TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

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ON-SITE ADVANCED OCCUPANT PROTECTION SYSTEM INVESTIGATION

VEHICLE: 2002 LEXUS ES300

GENERAL DYNAMICS CASE NO: CA02-047

LOCATION: TENNESSEE

CRASH DATE: OCTOBER 2002

Contract No. DTNH22-01-C-17002

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points are coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. CA03-047	*2. Government Accession No.*	*3. Recipient's Catalog No.*	
4. Title and Subtitle On-site Advanced Occupant Protection System Investigation Vehicle: 2002 Lexus ES300 Location: Tennessee		*5. Report Date*: January 2004	
		6. Performing Organization Code	
7. Author(s) Crash Data Research Center		*8. Performing Organization Report No.*	
9. Performing Organization Name and Address Transportation Sciences Crash Data Research Center Advanced Information Engineering Services P.O. Box 400 Buffalo, New York 14225		*10. Work Unit No.* C00410.0000.0074	
		11. Contract or Grant No. DTNH22-01-C-17002	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		*13. Type of Report and Period Covered* Technical Report Crash Date: October 2002	
		14. Sponsoring Agency Code	
15. Supplementary Note On-site investigation of a frontal crash of a 2002 Lexus ES300 equipped with an Advanced Occupant Protection System.			

16. Abstract

This on-site investigation focused on the performance of the Advanced Occupant Protection System (AOPS) in a 2002 Lexus ES300, **Figure 1**. The Lexus ES300 was equipped with front seat belt retractor pretensioners, dual-stage frontal air bags, side impact air bags, and inflatable head curtains. The vehicle was also equipped with an Event Data Recorder (EDR) that was capable of recording parameters associated to the crash. The Lexus was involved in an intersection crash with a 1999 Dodge Ram 1500 series pickup truck. The seat belt pretensioners and frontal air bags in the Lexus and the frontal air bags in the Dodge deployed as a result of the crash. The drivers of the respective vehicles sustained police reported minor injuries and refused treatment at the scene.

The crash was identified during routine sampling by researchers at NASS PSU 45 and was forwarded to the General Dynamics Special Crash Investigation team. The Crash Investigations Division of the National Highway Traffic Safety Administration assigned an on-site investigation to the General Dynamics SCI team upon subsequent notification. Cooperation was established with the Lexus's insurance carrier and permission was obtained to remove the vehicle's Event Data Recorder (EDR). The EDR was removed from the Lexus by the NASS researcher and forwarded to Toyota by NHTSA for data download.

17. Key Words Advanced Occupant Protection System AOPS Frontal impact Pretensioner Driver air bag EDR		*18. Distribution Statement* General Public	
19. Security Classif. (of this report) Unclassified	*20. Security Classif. (of this page)* Unclassified	*21. No. of Pages* 10	*22. Price*

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GENERAL DYNAMICS CASE NO: CA02-047
LOCATION: TENNESSEE
CRASH DATE: OCTOBER 2002

BACKGROUND

This on-site investigation focused on the performance of the Advanced Occupant Protection System (AOPS) in a 2002 Lexus ES300, **Figure 1**. The Lexus ES300 was equipped with front seat belt retractor pretensioners, dual-stage frontal air bags, side impact air bags, and inflatable head curtains. The vehicle was also equipped with an Event Data Recorder (EDR) that was capable of recording parameters associated to the crash. The Lexus was involved in an intersection crash with a 1999 Dodge Ram 1500 series pickup truck. The seat belt pretensioners and frontal air bags in the Lexus and the frontal air bags in the Dodge deployed as a result of the crash. The drivers of the respective vehicles sustained police reported minor injuries and refused treatment at the scene.

Figure 1: 2002 Lexus ES300

The crash was identified during routine sampling by researchers at NASS PSU 45 and was forwarded to the General Dynamics Special Crash Investigation team. The Crash Investigations Division of the National Highway Traffic Safety Administration assigned an on-site investigation to the General Dynamics SCI team upon subsequent notification. Cooperation was established with the Lexus's insurance carrier and permission was obtained to remove the vehicle's Event Data Recorder (EDR). The EDR was removed from the Lexus by the NASS researcher and forwarded to Toyota by NHTSA for data download.

SUMMARY

Crash Site

The crash occurred during the daylight hours of October 2002. At the time of the crash, the weather was clear and the road surface was dry. The crash occurred at the signalized intersection of a north/south divided road and the east/west entrance/exit ramps to a limited access highway. At the intersection, the northbound traffic way was configured with three lanes, two through lanes and a left turn lane. The southbound traffic way was configured with two lanes. A narrow curbed median [15 cm (6 in) barrier curbs] separated the northbound and southbound lanes. There was a positive grade (estimated greater than 2 percent) in the northbound direction. The speed limit in the area of the crash was 64 km/h (40 mph). **Figures 2 and 3** are northward and southward views of the intersection.

Figure 2: Northward view of the left turning traffic.

Figure 3: Southward look back view across the intersection.

CRASH SEQUENCE

Pre-Crash

The 2002 Lexus ES300 was traveling north in the left turn lane driven by a 47 year old female. The driver of the Lexus was restrained by the vehicle's 3-point lap and shoulder belt system. It was the driver's intention to turn left (westbound) onto the highway's entrance. The 1999 Dodge Ram was in the inboard southbound lane and was traveling through the intersection. The Dodge was driven by an unrestrained 29 year old male. The traffic light was in the green signal phase for the northbound/southbound traffic flow.

Crash

The crash occurred when the Lexus turned left across the path of the Dodge. The front right of the Dodge struck the front right corner of the Lexus in a 01/12 o'clock impact configuration. The angular corner impact rotated the Lexus counter-clockwise, which allowed the Dodge to engage the right front fender of the Lexus. The force of the impact fired the retractor pretensioners in the Lexus and commanded the deployment of the frontal air bag system at 32 milliseconds. The frontal air bags in the Dodge also deployed. The total delta V calculated by the WINSMASH was 35.9 km/h (22.3 mph) and 24.8 km/h (15.4 mph) for the Lexus and Dodge, respectively. The EDR recorded delta V was 38.6 km/h (24.0 mph) at 150.0 milliseconds.

The southbound momentum of the Dodge and its engagement forward of the Lexus's center of gravity caused the Lexus to rotate counterclockwise as the vehicles separated from the impact. The Lexus rotated approximately 160 degrees and came to rest facing south on the west road shoulder approximately 17m (55 ft) from the point of impact. The Dodge rotated approximately 30 degrees clockwise and came to rest straddling the southbound lane divider approximately 13 m (43 ft) south of the impact. **Figure 12** is a schematic of the crash.

Post-Crash

The police responded to the crash scene. Both drivers had exited their respective vehicles under their own power and refused medical treatment. The vehicles were towed due to the disabling damage and were considered a total loss by their respective insurance carriers.

VEHICLE DATA

2002 LEXUS ES300

The 2002 Lexus ES 300, **Figure 4**, was identified by the Vehicle Identification Number (VIN): JTHBF30GX20 (production sequence deleted). The 4-door sedan was equipped with a 3.0 liter/V6 engine linked to a 5-speed automatic transmission. The service brakes were four-wheel disc with four sensor/four channel ABS. The manual restraint system consisted of 3-point lap and shoulder belts in the five seat positions. The front restraints were equipped with retractor pretensioners. The Advanced Occupant Protection System (AOPS) consisted of dual stage driver and front right passenger air bags. Additionally, the Lexus was equipped with front seat back mounted side impact air bags and inflatable side curtains. The electronic odometer could not be read at the time of the inspection. The vehicle's date of manufacture was November 2001. The subject vehicle was equipped with Toyo Proxes tires (size P215/60R16) on OEM alloy wheels. The manufacturer's recommended tire pressure was 200 kpa (29 psi). The specific measured tire data was as follows:

Figure 4: Left front view of the Lexus.

Tire	Measured Pressure	Tread Depth	Restricted	Damage
LF	196.5 kpa (28.5 psi)	3.2 mm (4/32)	No	None
LR	158.6 kpa (23.0 psi)	4.8 mm (6/32)	Yes	Rim fractured
RF	206.8 kpa (30.0 psi)	4.0 mm (5/32)	No	None
RR	200.0 kpa (29.0 psi)	4.8 mm (6/32)	No	None

Exterior Damage

Figure 5 is a front view of the damaged Lexus. The front plane of the Lexus sustained 23.6 cm (9.3 in) of direct contact damage that began 49.0 cm (19.3 in) right of center and extended to the right corner. The combined width of the direct and induced damage extended across the vehicle's entire 145 cm (57 in) front end width. Additionally, the direct contact damage pattern extended rearward 199.6 cm (78.6 in) along the right side and ended on the forward aspect of the right front door. The nature of the impact damage was indicative of an angular corner impact with engagement of the Dodge onto the right side plane of the Lexus. The right front fender buckled and shifted rearward fracturing the right lower aspect of the windshield. The right front door compressed into the B-pillar and was jammed closed. The compression of the door caused the window frame to bow outward. The right front tire, wheel, and suspension were damaged. The right wheelbase was foreshortened 4.1 cm (1.6 in). The force of the impact caused localized buckling of the roof and right rear quarterpanel. The residual crush profile measured along the bumper reinforcement was as follows: C1 = 0, C2 = 1.0 cm (0.4 in), C3 = 5.0 cm (2.0 in), C4 = 11.0 cm (4.3 in), C5 = 14.0 cm (5.5 in), C6 = 25.0 cm (9.8 in). The Collision Deformation

Classification (CDC) was 01-FREE-6. The total delta V calculated by Damage algorithm of the WINSMASH model was 35.9 km/h (22.3 mph). The longitudinal and lateral delta V components were -31.1 km/h (-19.3 mph) and -18.0 km/h (-11.2 mph), respectively.

Figure 5: Front view of the Lexus.

Figures 6 and 7 are close-up views of the damaged right forward frame member and the undamaged left forward frame member, respectively. The right side frame member's longitudinal crush measured 25.0 cm (9.8 in).

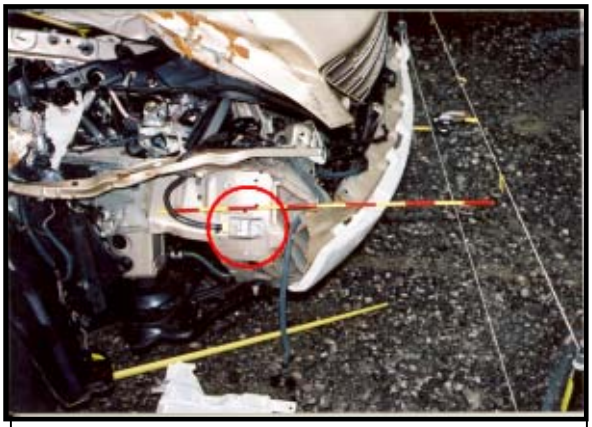

Figure 7: Lateral view of the crush at the right forward frame.

Figure 6: Lateral view of the undamaged left forward frame.

Interior Damage

The interior damage to the Lexus consisted of minor lateral intrusion associated to the exterior forces of the corner impact, the deployment of the vehicle's frontal air bags and minor occupant interior contacts. The lateral intrusion at the corner of the right instrument panel was 1.9 cm (0.75 in). The interior panel of the right front door was compressed against the right outboard aspect of the instrument panel.

The 6-way power driver seat was adjusted to a mid-track position. The seat back angle measured reclined 27 degrees. The seat could not be moved due to a lack of electrical power and was determined to be adjusted to its at-crash position. The horizontal measurement from the center hub of the steering wheel to the seat back measured 61.7 cm (24.3 in).

The 3-spoke steering wheel rim was rotated 180 degrees at the time of inspection. The tilt steering wheel/column was adjusted to the center position. There was no deformation of the steering wheel rim. Examination of the steering column revealed 64 mm (0.25 in) of separation on both (right and left) shear capsules. The shear separation was caused by the inertial loading imparted to the column as the driver rode down the force of the crash.

Manual Restraint System

The manual restraint system in the 2002 Lexus ES 300 consisted of a 3-point lap and shoulder belt with a sliding latch plates and continuous loop webbing in the five seat positions. The inertial locking retractors for the front restraints were equipped with retractor pretensioners. The front pretensioners fired as a result of the crash. The D-rings for the front restraints were vertically height adjustable.

Figure 8: View of the driver's manual restraint.

At the time of the inspection, the driver's restraint was extended from the retractor and laying on the seat, **Figure 8**. The retractor was locked. The D-ring was positioned 1.9 cm (0.75 in) above its lowest adjustment. The exposed webbing section measured 179.1 cm (70.5 in) from the outboard anchor to the adjustable D-ring. The exposed webbing in the lap portion of the belt measured 80.6 cm (31.75 in) and the exposed webbing in the torso section measured 98.4 cm (38.75 in). Examination of the webbing revealed a 4 cm (1.5 in) section of stretched webbing located at the latch plate with the restraint in the buckled condition. Examination of the latch plate revealed evidence of historical use consistent with the age of the vehicle. All the evidence gathered during the inspection indicated the driver was restrained at the time of the crash.

The front right restraint was stowed within its retractor and the webbing was under tension. The condition of the belt indicated the retractor pretensioner had fired. The trim panel surrounding the D-ring was displaced. It appeared that the adjustable D-ring had been displaced beyond its lowest position, as a result of the tension placed on the belt by the fired pretensioner.

Advanced Occupant Protection System

The Advanced Occupant Protection System (AOPS) in the Lexus ES300 consisted of dual stage driver and front right passenger air bags. The Lexus was also equipped with front seat back mounted side impact air bags and inflatable side curtains. The frontal air bags deployed as a result of the frontal crash. The AOPS was monitored and controlled by a control module

mounted under the forward aspect of the center console. The control module had Event Data Recording (EDR) capabilities. Two crash recognition sensors were located on the forward uni-body frame and are highlighted in **Figures 6 and 7** above.

Figure 9: Driver air bag.

The driver air bag was housed in the typical manner in the center hub of the steering wheel. The H-configuration module cover flaps were asymmetrical. The upper flap measured 14.7 cm x 6.4 cm (5.8 in x 2.5 in); width by height, and the lower flap measured 14.7 cm x 10.1 cm (5.8 in x 4.0 in). The driver air bag measured 66 cm (26 in) in its deflated state. It was tethered by two 10 cm (4 in) wide straps sewn to the face of the bag. It was vented by two 3.3 cm (1.3 in) diameter ports in the 11/1 o'clock sectors on the back side of the bag. **Figure 9** is a view of the driver air bag. The contact evidence on the face of the driver air bag consisted of three areas of make-up transfer. The transfers measured 1.9 cm (0.75 in) in diameter, 2.5 cm x 8.9 cm (1.0 in x 3.5 in), width by height and 1.3 cm x 6.4 cm (0.5 in x 2.5 in), width by height. The transfers were located symmetrically along the vertical centerline of the air bag indicative of the driver being "in-position" at the time of the contact.

The front right passenger air bag was a top mount design located in the right aspect of the instrument panel. The module cover flap was incorporated into the design of the instrument panel and consisted of a 22.1 cm x 7.6 cm (8.8 in x 3 in) single vinyl flap hinged on the module's rearward side. The face of the passenger air bag measured 40.6 cm x 55.8 cm (16.0 in x 22.0 in) and extended 30.5 cm (12.0 in) rearward from the vertical face of the instrument panel. The bag was not tethered and was internally vented. There was no occupant contact evidence identified on the passenger air bag.

Event Data Recorder

The EDR was located under the center electronic stack forward of the transmission shifter. Access to the module required disassembly of the center console. Prior to SCI involvement in the investigation, the NASS Researcher was instructed by NHTSA to obtain the EDR module. The NASS researcher obtained the required permission from the insurance carrier, removed, and then shipped the module to the Crash Investigation Division (CID). The CID in-turn forwarded the module to Toyota for analysis. Upon internal analysis, Toyota forwarded a translation of the stored data to NHTSA.

The EDR had the capability to store pre-crash and crash-related data. The EDR reported the following information:

- The driver seat belt buckle switch was in the buckled condition (representing a belted driver).
- The front right passenger seat belt buckle switch was not buckled.
- A "Hi" air bag deployment level was reported for both frontal air bags. The "Hi"

terminology probably referred to a Stage 2 deployment (although this was not verified).

- The air bags deployed 32 milliseconds after crash recognition.
- The air bag warning lamp in the instrument cluster was not illuminated at the time of the crash
- There were no stored diagnostic faults.
- The crash severity in terms of delta V was reported for 150 milliseconds in 10 millisecond intervals. The maximum-recorded delta V was 38.6 km/h (24.0 mph).

The EDR also recorded five seconds of pre-crash data representing the vehicle speed, engine rpm, throttle position and brake switch status. The data indicated the vehicle speed was a constant 126.0 km/h (78.3 mph), engine rpm was a constant 6000 rpm, the throttle position was reported as false interpreted as a closed throttle and the brake switch was on. The recorded pre-crash data was considered unreliable. Reconstruction of the crash revealed the Lexus was turning left at a low to moderate speed approximately 24 – 40 km/h (15 – 25 mph). The reported engine rpm was inconsistent with the operation of the 3.0 liter V6 engine particularly with a closed throttle. Additionally, the brake switch status was inconsistent with the reconstructed vehicle dynamics.

1999 DODGE RAM 1500

The 1999 Dodge Ram 1500 Pick-up truck was identified by the Vehicle Identification Number (VIN): 3B7HF13Y0XG (production sequence deleted). The 4x4 club-cab was manufactured in January 1999. The vehicle had a gross registered weight of 2,722 kg (6,000 lbs) and had a 352.3 cm (138.7 in) wheelbase. The manual restraint system consisted of 3-point lap and shoulder belts in the four outboard positions and two center lap only belts. The Supplemental Restraint System consisted of driver and front right passenger air bags. The cut-off switch for the passenger air bag was in the "Air Bag On" position. The electronic odometer could not be read at the time of the inspection.

Exterior Damage

Figures 10 and 11 are the front and right lateral views of the damaged Dodge. The front plane of the Dodge sustained a 143.5 cm (56.5 in) of direct contact damage that began 57.1 cm (22.5 in) left of center and extended to the right corner of the front bumper. The combined width of the direct and induced damage extended across the entire 173 cm (68 in) frontal end width. The damaged components included the front bumper, center grille, hood, right headlamp assembly and right front fender. The damage extended rearward into the engine compartment to the radiator support plane. The residual location of the right corner of the bumper was inboard of the right front tire. The right front tire was deflated and the exterior surface of the rim was abraded. The right wheelbase was reduced 1.9 cm (0.75 in). The right front fender shifted rearward and restricted the operation of the right front door. There was no cab to bed contact. The residual crush profile measured at the bumper elevation was as follows: C1 = 0, C2 = 19 cm (7.3 in), C3 = 41 cm (16.0 in), C4 = 46 cm (18.3 in), C5 = 38 cm (15.3 in), C6 = 41 cm (16.0 in). The Collision Deformation Classification was 12-FDEW-2. The total delta V calculated by Damage algorithm of the WINSMASH model was 24.8 km/h (15.7 mph). The longitudinal and lateral delta V components were -24.8 km/h (-15.7 mph) and 0, respectively.

Figure 10: Front view of the Dodge.

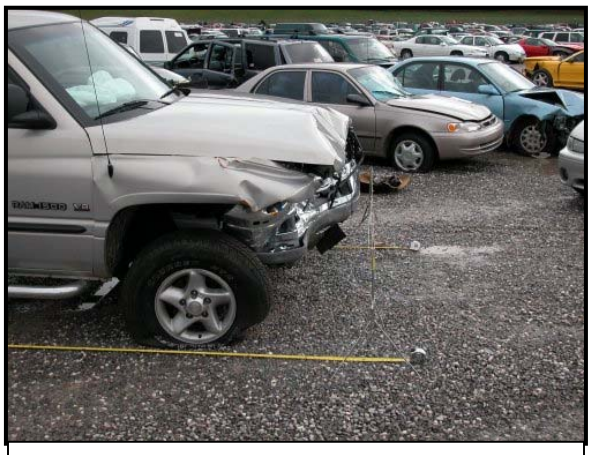

Figure 11: Right lateral view.

Interior Inspection

The interior damage to the Dodge was consistent with the deployment of the frontal air bags and occupant interior contacts. There was no intrusion associated to the exterior forces of the crash. There was no evidence of contact to the driver knee bolster.

The driver seat was located in a mid-track position and measured 8.9 cm (3.5 in) forward of full rear. The total seat track travel was 20 cm (8 in). The seat back was reclined 10 degrees. The horizontal measurement from the driver air bag module to the seat back measured 60.5 cm (23.8 in). The steering column was loaded by the driver through the air bag during the ride-down of the crash and was completely separated from the shear capsules.

The driver's 3-point lap and shoulder restraint was integrated in the seat. The restraint was stowed at the time of the inspection and the retractor was locked. The webbing could not be extended. The latch plate displayed evidence of historical use; however, inspection of the exposed webbing revealed no indicators of use during this crash. All the evidence gathered during the inspection indicated the driver was not restrained at the time of the crash.

The driver air bag was housed in the typical manner in the center hub of the steering wheel. The H-configuration module cover flaps were asymmetrical. The upper flap and lower flap measured 14.0 cm x 10.1 cm (5.5 in x 4.0 in) and 14.0 cm x 2.5 cm (5.5 in x 1.0 in), respectively. The driver air bag measured 56 cm (22 in) in its deflated state. It was tethered and internally vented. Vinyl transfers were noted on the back side of the bag in the 3/9 o'clock sectors indicative of contact to the steering wheel spokes. The driver air bag module displayed some minor deformation associated to being over-pressurized. The expansion of the module had contacted and damaged the cruise control buttons located on the left and right sides of the steering wheel spokes. The contact evidence identified on the driver air bag was consistent with the ride-down of an unrestrained driver.

The passenger air bag was a top mount design located in the right aspect of the instrument panel.

The air bag module was rectangular in shape and the cover flap measured 27.9 cm x 19.8 cm (11.0 in x 7.8 in). The face of the bag measured 86 cm x 56 cm (34 in x 22 in), width by height, in its deflated state. The rearward excursion of the bag measured 51 cm (20 in) from the aft edge of the module. The passenger air bag was shaped to offer protection to a center-seated occupant. The air bag was not tethered and was internally vented. There was no contact evidence identified on the bag.

OCCUPANT DEMOGRAPHICS

	Driver 2002 Lexus ES300	***Driver 1999 Dodge Ram 1500***
Age/Sex:	47 year old/Female	29 year old/Male
Height:	Unknown	Unknown
Weight:	Unknown	Unknown
Manual Restraint Use:	3-point lap and shoulder	None
Usage Source:	SCI inspection, PAR	SCI inspection
Seat Position:	Mid-track	Mid-track
Medical Treatment	None, not injured	None, not injured

After the crash, the driver's exited their respective vehicles. Reportedly, both drivers were sore and refused medical transport.

DRIVER KINEMATICS

2002 Lexus ES300

The 47 year old driver of the Lexus was restrained at the time of the crash and was seated in a presumed upright posture. The driver's seat was adjusted to a mid-track position. Upon impact, the retractor pretensioners fired and the frontal air bags deployed. The driver's retractor pretensioner removed slack from the driver's manual restraint and tightened the webbing about the driver. The driver initiated a forward trajectory in response to the 01 o'clock direction of the impact force and loaded the manual restraint. The driver contacted the inflated air bag with her face evidenced by the make-up transfers. The driver also loaded the air bag with her chest. Her loading force was transmitted through the deployed air bag and into the steering column. As a result, the column compressed 0.6 cm (0.25 in) as evidenced by the shear capsule displacement. The combination of the manual restraint system and driver air bag offered the driver adequate protection as she rode down the force of the crash.

1999 Dodge Ram 1500 Pick-up truck

The 29 year old driver of the Dodge was unrestrained and seated in a mid-track position at the time of the crash. Upon impact, the frontal air bag system in the Dodge deployed. The driver initiated a forward trajectory in response to the 12 o'clock direction of the impact. He loaded the deployed driver air bag with his chest and rode down the impact. The driver loaded the steering column through the deployed air bag and displaced the column from the shear capsules. He then rebounded back into his seat.

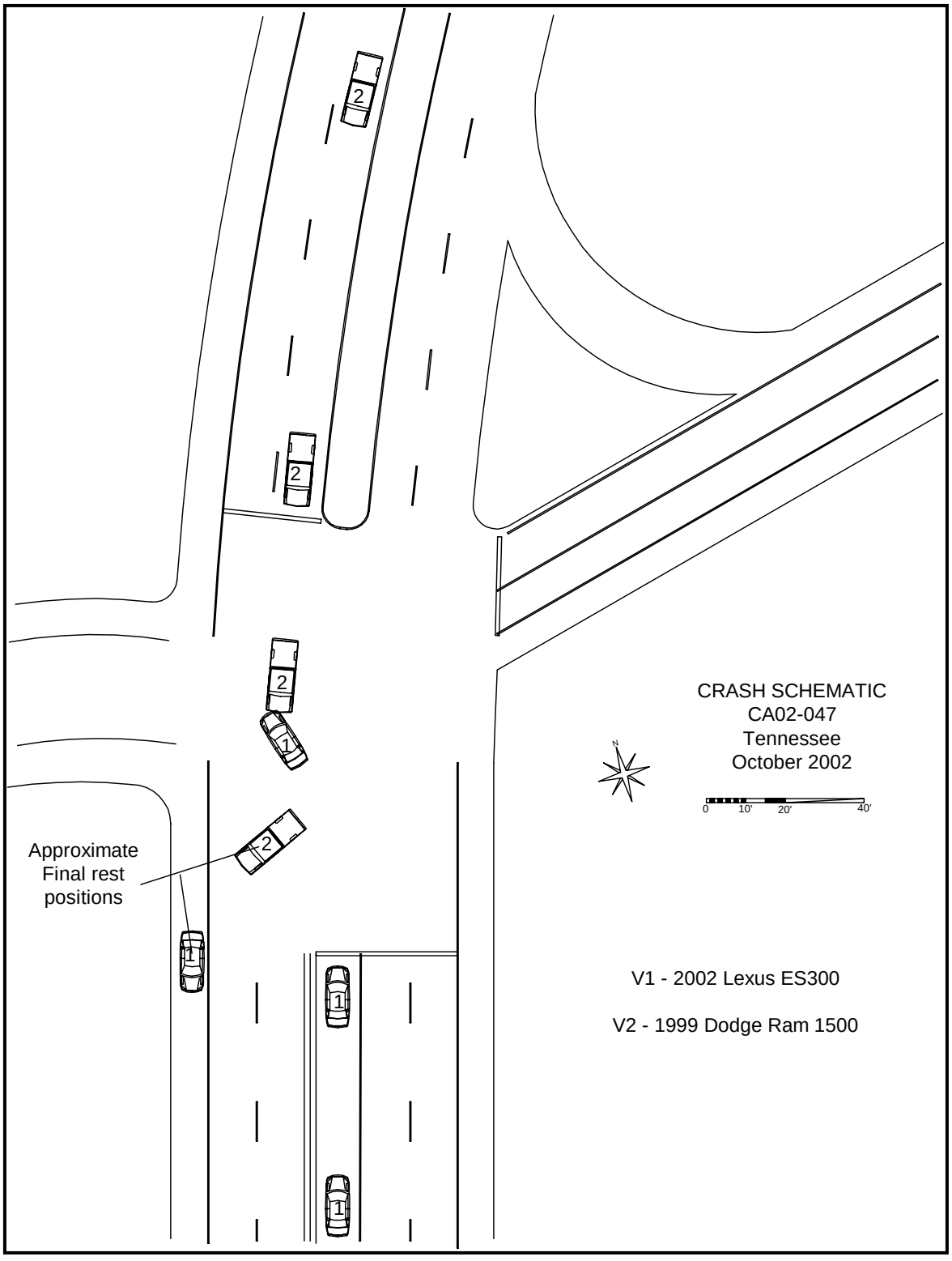

Figure 12: Crash schematic.